involving debris that forms in a very extended disk of material that extends far out beyond the boundaries of the current satellite system. A small amount of gas remaining in this disk causes solid material to drift slowly inward onto the outermost moon, accreting without providing much heating. In addition, a study of the thermal internal evolution of a realistic Callisto was carried out, including ice-phase-change boundaries and plastic ice convection, showing that a sufficiently slow accretion rate would indeed preclude melting of the icy component and prevent complete differentiation of the icy and rocky material.

Ames maintains the Planetary Data System Rings Node (http://ringmaster.arc.nasa.gov/), which archives and distributes ring data from NASA's spacecraft missions and from Earth-based observatories. The entire archive of images from the Voyager missions to the giant planets is now on line, with catalogs to help users find the images they need. Interactive search and geometrical visualization utilities are also available to assist Cassini scientists in planning observations of the rings during the upcoming tour (2004–2008). Ames also provides the Cassini project with the Interdisciplinary Scientist for Rings and Dust, who chaired the Rings Discipline Working Group this year as it worked through initial ring science sequence planning.

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Vortex Evolution in a Protoplanetary Disk

Sanford Davis

The theory that planets form from a thin disk of dust and gas was first proposed in the 18th century and is now a generally accepted fact. The process by which planets actually emerge from this tenuous state is a subject of intense current study. Recent research points to vortex motion as a possible intermediary where dust particles are captured, concentrated, and finally accumulated by gravitational attraction. These mass accumulations gradually grow to kilometer-sized objects (planetesimals) and ultimately to full-sized planets. With the assumption that the disk can support a turbulent flow, it was shown that vortices arise naturally and persist as long as turbulent energy is present. Other possibilities are that vortices arise from certain instabilities in the rotating disk or from external impacts of clumpy infalling gas. In either case, coherent vortices could lead to important and far-reaching processes in the protoplanetary disk.

A research study is under way to determine the effect of vortices on the wave structure in a typical disk, which may also play a role in the planet-formation process. It is well-known that discrete vortices in a sheared flow do not retain their coherence. This coherence time depends on the local shear rate, the strength, and the size of the vortex. During the shearing epoch, and depending on the nature of the medium, a vortex can emit a variety of wave systems. In this study, the equations of motion have been simulated using a high-resolution numerical method to track Rossby and acoustic/shock waves. Rossby waves are slowly moving waves of vorticity generated in flows with large-scale vorticity gradients. Acoustic waves are waves of expansion and contraction that occur in all compressible media. The protoplanetary disk is a rotating compressible gas with a radially variable rotation rate. It can support both wave systems.

A typical result from the simulation is given in figure 1, which shows a sequence of snapshots of the perturbed vorticity defined as the difference between the total vorticity and the baseline flow. This baseline flow is a Keplerian flow (Rotational velocity = Constant x (Radius)$^{-1/2}$), and the initial vortex is shown in the third quadrant in figure 1(a). The vortex becomes elongated about its initial location at $r = 4$ (blue-red streaks on the white circle in fig. 1(b)), and both inward- and outward-bound counterclockwise spiral vorticity waves are spawned. The outward-bound waves evolve to an axisymmetric wave pattern (circularization) with shock waves (fig. 1(d)). It is interesting that the vortex-induced waves can induce a supersonic radial flow. Another wave system (Rossby waves) appears in the region $r < 10$. The shock waves are axisymmetric, whereas the Rossby waves have a cosine angular dependence. Each wave system has a characteristic radial speed.

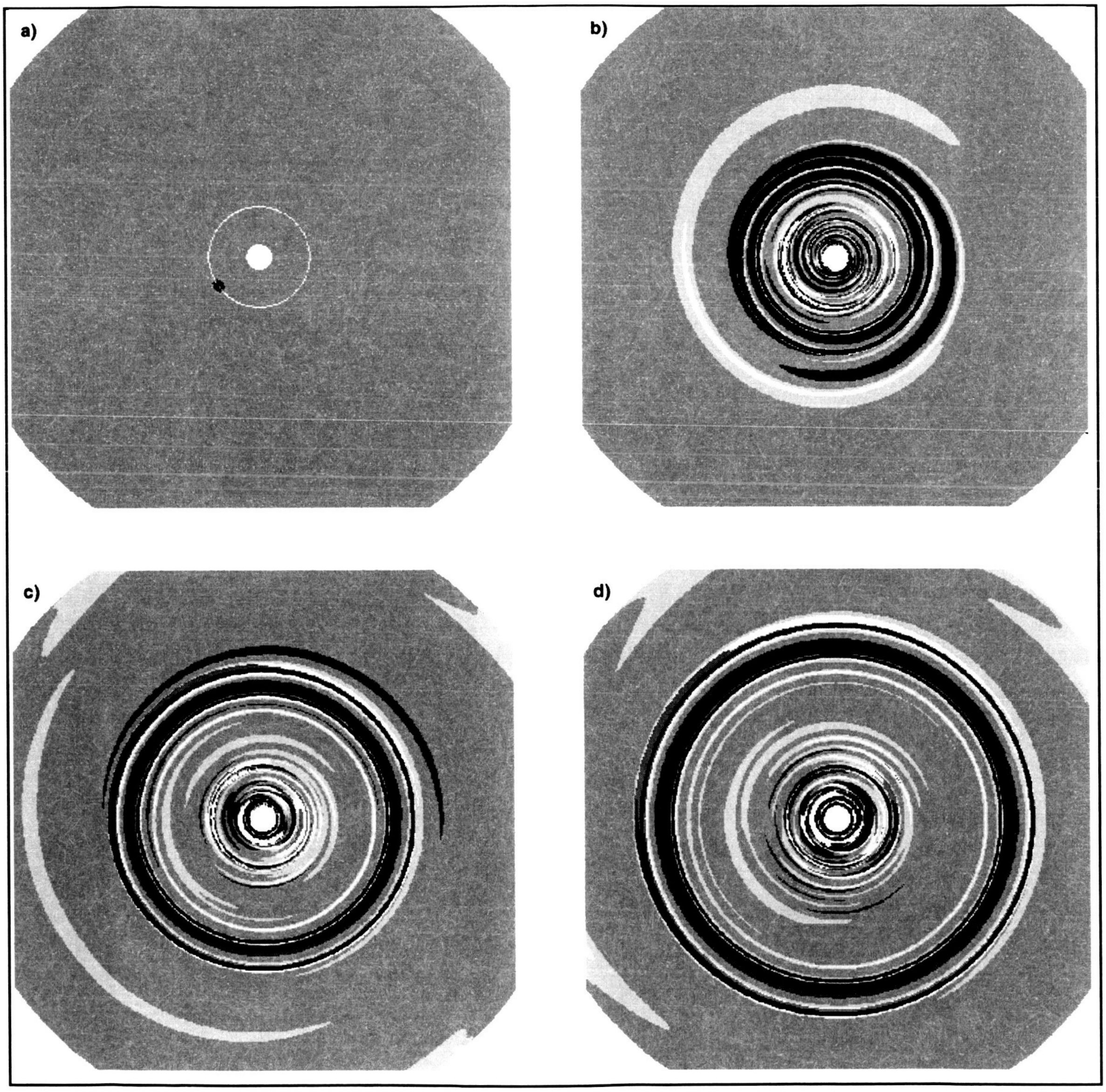

Fig. 1. Perturbation vorticity bitmaps showing density (shocks) and Rossby waves. (a)–(d): 0, 16, 32, and 48 vortex revolutions, respectively.

Follow-up work will augment the numerical simulations with particle and/or granular gas models to examine the effect of these vorticity-induced waves on particle migration, accumulation, and (possibly) planetesimal formation.

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Liquid Water on Present-Day Mars?

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Near-surface environmental conditions on Mars today are generally considered inadequate to permit liquid water to exist in equilibrium with the atmosphere. Mean annual temperatures are about 50–60 kelvin (K) below the melting point, and mean annual surface pressures are very close to the triple point. Yet there are localized regions where, for a few hours of the day at the right time of year, surface temperatures and pressures meet the minimum requirements for the existence of liquid water: pressures and temperatures above the triple point of water but below the boiling point.

That such conditions do exist was determined using a validated General Circulation Model. The model predicts where and for how long liquid water could exist each Martian year. For pure liquid water, the model predicts that liquid water might occur in five regions: between 0 and 30 degrees North in the plains of Amazonis, Arabia, and Elysium; and in the Southern Hemisphere impact basins of Hellas and Argyre. The combined area of these regions represents 29% of the surface area of the planet. In the Amazonis region, these requirements are satisfied for a total integrated time of 37 sols each Martian year. In the Hellas basin, the number of degree-days above 0 is 70, a number that is well above those experienced in the dry valley lake region of Antarctica.

Whether liquid water ever forms in these regions depends on the availability of ice and heat, and on the evaporation rate. The latter is poorly understood for low-pressure CO_2 environments, but is likely to be so high that melting occurs rarely, if at all. However, even rare events of liquid-water formation would be significant because they would dominate the chemistry of the soil, and would have biological implications as well.

Interestingly, these regions are remarkably well correlated with the location of impact craters that appear to have been filled with lakes at some time in the past. Approximately 86% of the more than 100 impact crater lakes lie within the model-predicted regions where conditions for liquid water are favorable. The lakes do not exist today, but appear to have existed within the last several billion years, and some appear to have existed within the last several hundred million years. The reason for this amazing correlation is not known.

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